Hyperloop Cheetah

Wheel design feasibility study

Analysis by Kristian Zimmermann of a wheel design by Richard Macfarlane

3/12/2014

[Type the abstract of the document here. The abstract is typically a short summary of the contents of the document. Type the abstract of the document here. The abstract is typically a short summary of the contents of the document.]

Contents

Introduction 2
Design/ Material 2
Results 3
Fail safety 6
Excurse/ Validation 7
Conclusions 9
Works Cited 9

Introduction

For the ‘Cheetah’, see Macfarlane (1) a wheeled concept has been proposed for the Hyperloop. The following report is a feasibility study of the concept wheel based on a finite element analysis (FEA). Only a single iteration is calculated.

Design/ Material

For the majority of the components CFRP (carbon fiber reinforced plastic) is proposed. A proper sizing has not been performed, i.e. fastener edge distance, fastener pitch etc. Dimensions for the analysis are derived directly from the CAD model, see Figure 1.

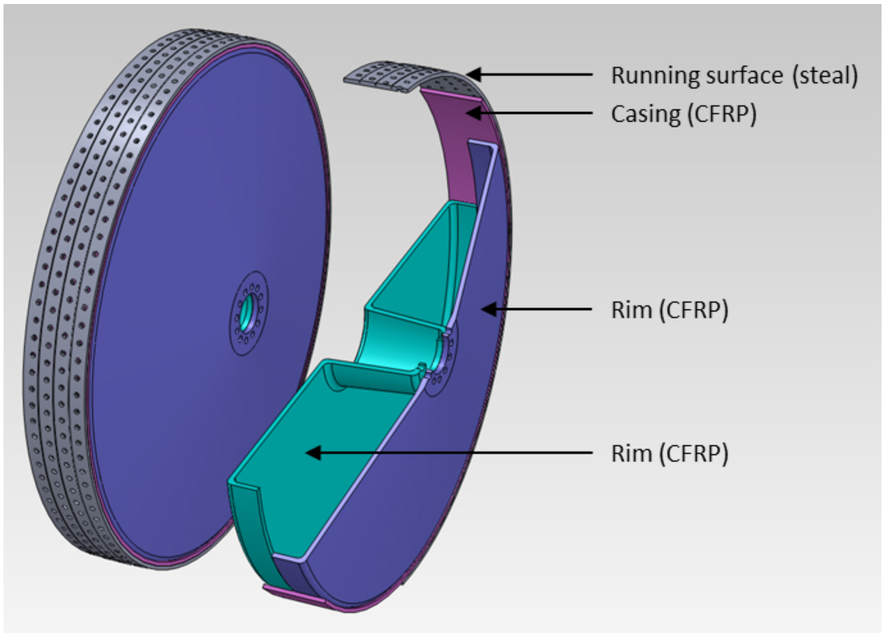


Figure 1: CFRP wheel layout.

For dimensions and speeds please refer to Figure 2 and Table 1.

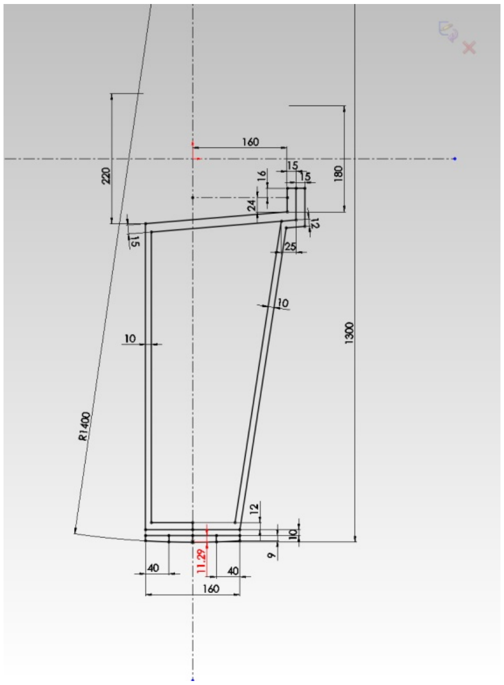


Figure 2: Wheel dimensions.

Table 1: Wheel diameters and rotational speeds.

d	U	ω		R1	R2
[m]	[rpm]	[rad/s]	[1/s]	[m]	[m]
1.3	**4897**	**513**	**82**	0.1	**0.65**

Carbon fiber plies are applied in stacks of eight plies with 45° increments to form a full 360° circle. The outer casing features additional 0° plies for added circumferential stiffness.

Results

The lateral deflection is illustrated in Figure 3. Due to the asymmetric design, lateral forces bend the wheel to one side (max 14mm).

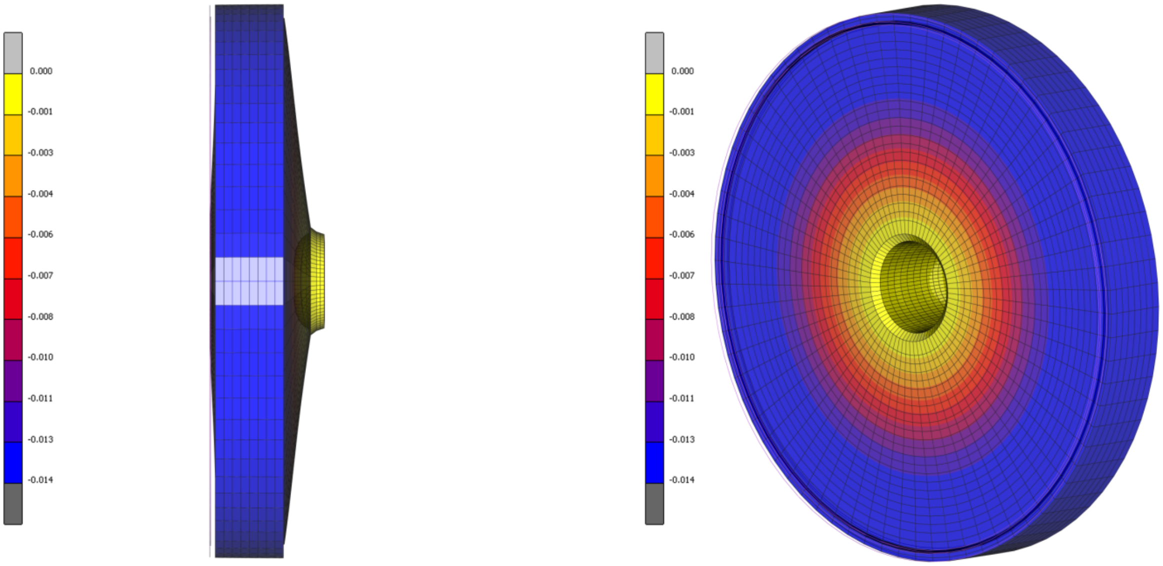


Figure 3: Lateral deflection

Figure 4 illustrates the radial deflection (max 2mm).

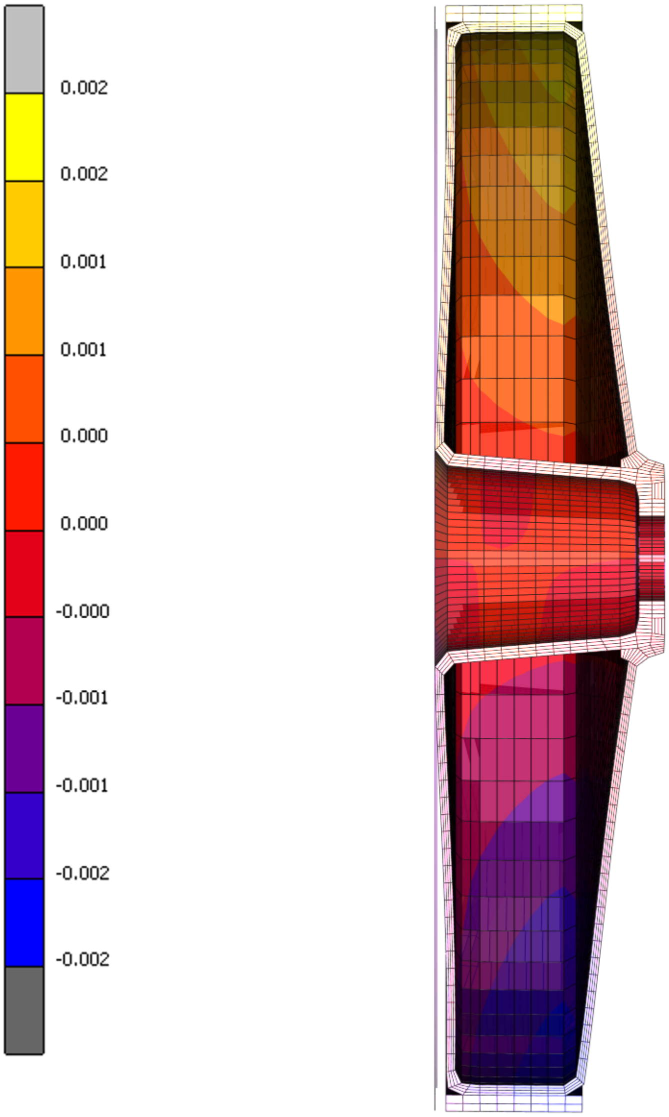


Figure 4: Radial deflection.

Radial stresses are transferred via the rim surfaces to the radii that converge to the running surface. Here peeling stresses are confronted with low out of plane strength properties of the laminate. The stress level should be kept below σ_{33}=35MPa. This is currently achieved, see Figure 5. It should however be mentioned that mesh density is low in the critical region. A further refinement is advised.

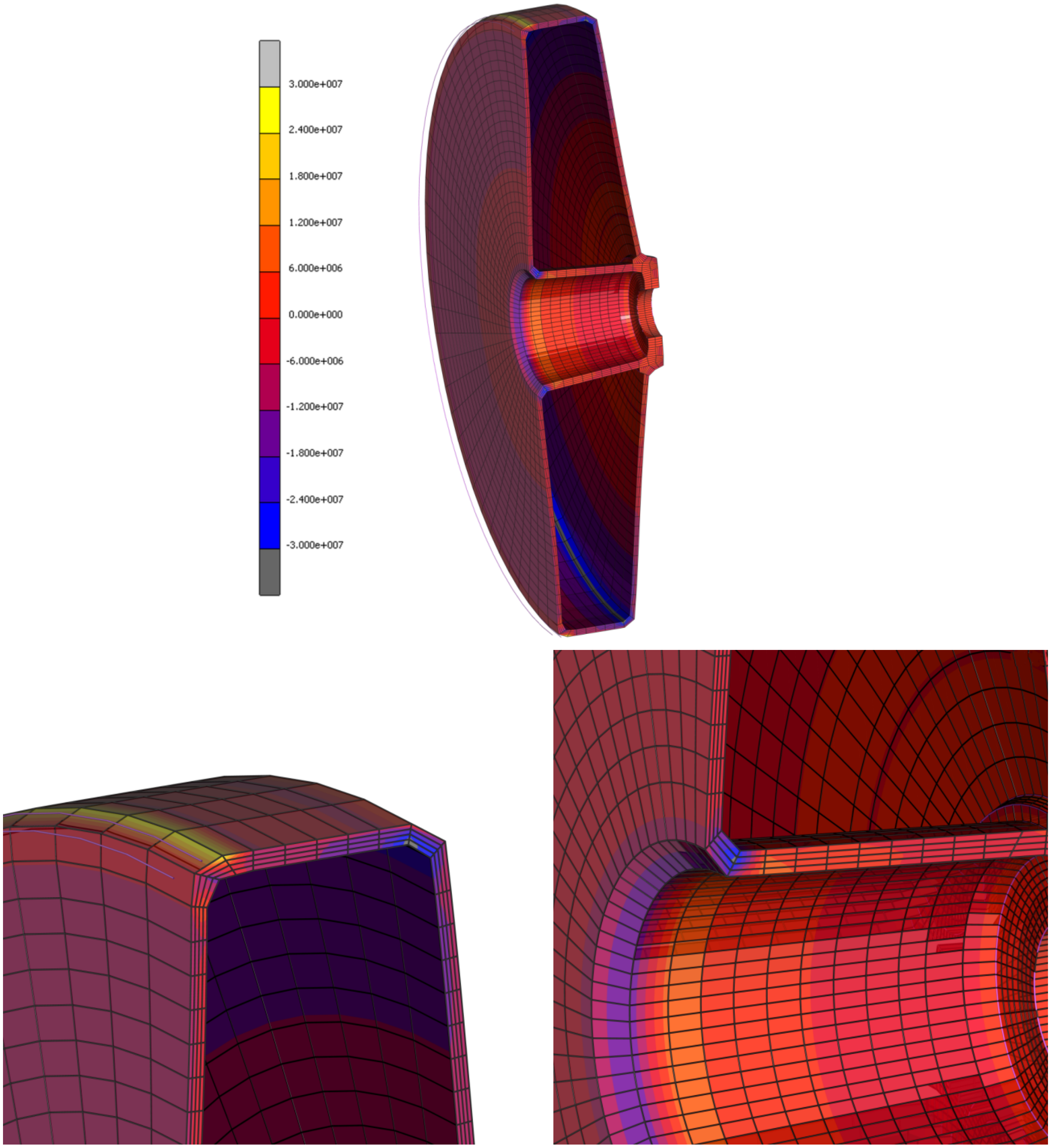


Figure 5: Out of plane stresses.

In plane stresses (σ_{11}, σ_{22}, σ_{12}) are not plotted, but stay within reasonable limits. An interactive failure criterion can be applied at a later stage.

Fail safety

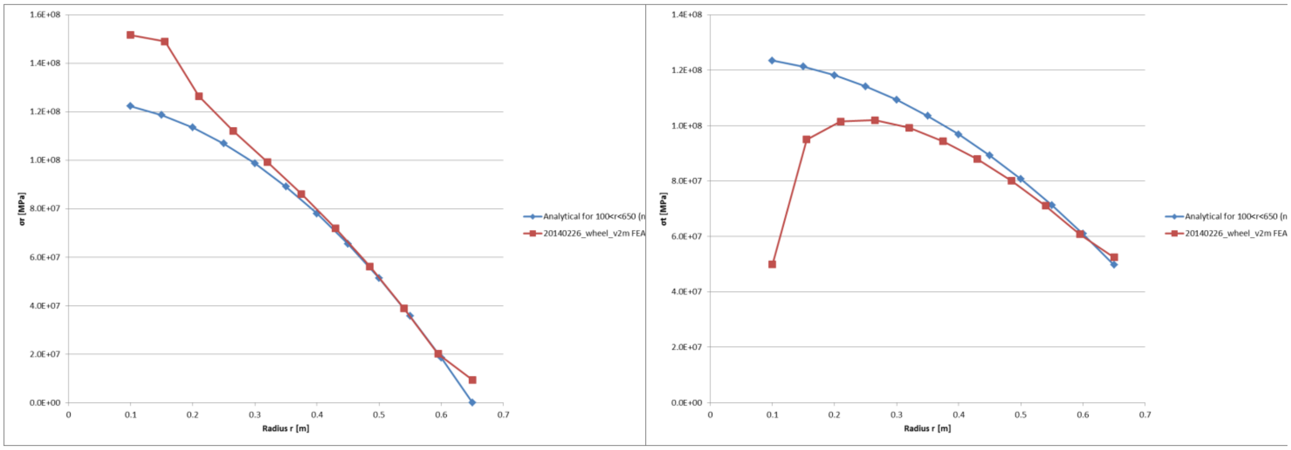
The wheel should be a fail-safe design, in order to increase safety and reduce maintenance efforts. A failure is not allowed to cause a catastrophic failure of the entire capsule.

Considerations

- Parts which come of need to be contained
- Preferably only smaller parts can come off
- A failure should be contained within the wheel
- Cracks are not allowed to grow uncontrollably

Excurse/ Validation

Prior to the analysis of the CFRP design, a simple disk has been calculated and compared to analytical results in order to verify the FE- results. The results are shown in Figure 6. Both the the analytical and finite element model include a D=200mm hole. The hole of the finite element model has a fixed edge, which leads to different results compared to the analytical model.



Radial stresses [Pa]

Tangential stresses [Pa]

Figure 6: Stress comparison for steel disk.

The radial deflection is illustrated in Figure 7.

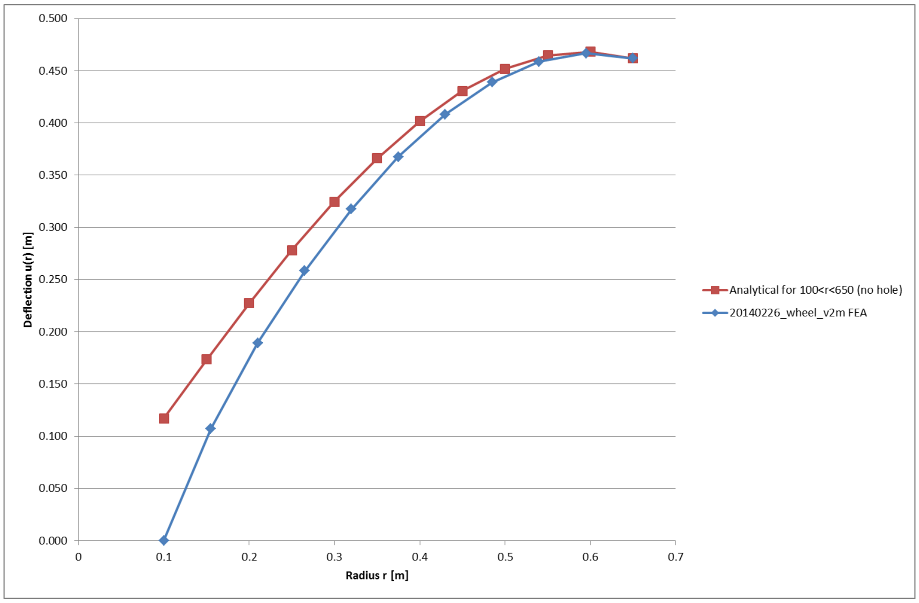
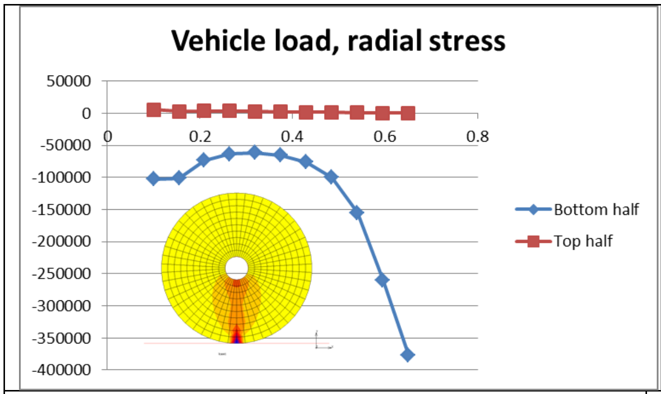
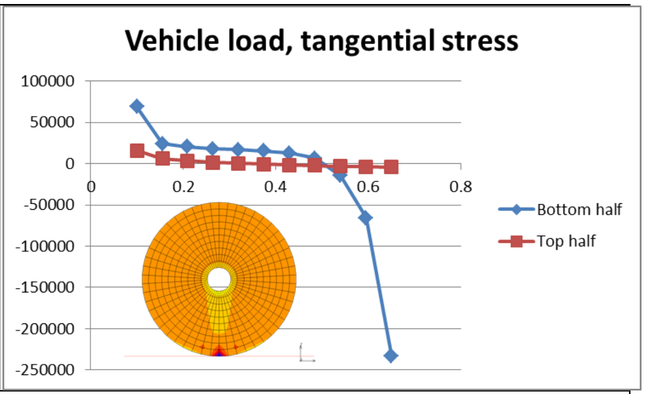
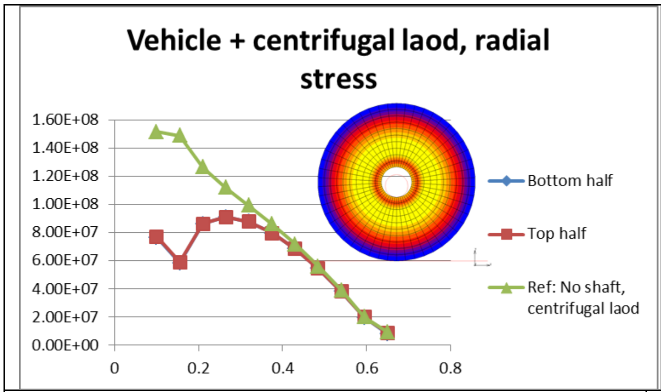


Figure 7: Radial deflection, analytical vs. FEA.

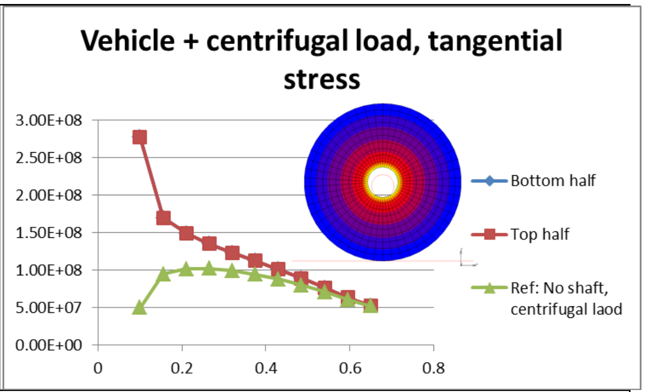
In addition the influence of the vehicle load is investigated. For that purpose a contact algorithm is applied simulating the shaft and floor. The direct influence of the vehicle load (estimated 22kN) is negligible. The one sided contact of the shaft does however have a profound influence and the stress distribution close to the shaft; tangential stresses are increased whereas radial stresses are decreased, see Table 2. For the CFRP wheel design a contact algorithm has not been included in order to reduce the computational effort.

Table 2: Stress comparison, with & without vehicle load.

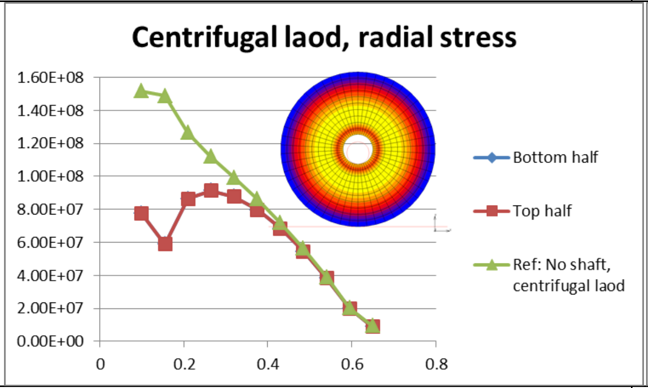
	
Radial stress with vehicle load only.	Tangential stress with vehicle load only.



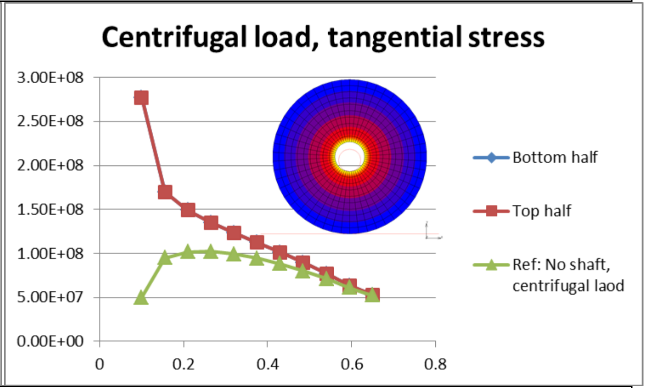
Radial stress with vehicle and centrifugal load.



Tangential stress with vehicle and centrifugal load.



Radial stress with centrifugal load only.



Tangential stress with centrifugal load only.

Conclusions

Based on the current FE results a CFRP wheel design seems feasible from a static point of view. The analysis does not take into consideration dynamic effects, fatigue etc. Several design iterations are required in order to optimize and validate the design. CFRP components are highly manufacturing driven. Aspects such as drapability need to be shown.

Works Cited

1. **Macfarlane, Richard.** CAPSULE Working Group. [Online] JumpStartFund,

Hyperloop Cheetah proposal here